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"Means of Screw-Ship Steerage, and a Description of the Hydrostatic Steering-Gear Fitted on Board H.M. Ship 'Achilles,' with the Results of Experiments at Sea; also Plan of Apparatus Fitted on Board the Turkish Iron-Clad 'Fethi Bulend.' "

Rear-Admiral E. A. Inglefield C.B., F.R.S.

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Indiamen—I would tell Captain Selwyn, for his satisfaction, where they have been very full vessels aft, the steering was wild, that the very fact of putting these blades upon them has made them very handy indeed. I have only to say I thank the gallant officers for their kind remarks, and that my mind is open to any discussion on the matter. As Captain Selwyn says, there may be more purposes got out of this simple application of the laws of nature, which remain still to be developed. I am not above learning, and hope to obtain many valuable hints still on the subject. I would also thank Admiral Halsted for his very kind and honest remarks. I know that he is not one to flatter an invention, but is determined to see its value. I take his remarks as a golden opinion, which I accept from the gallant Admiral, and I shall leave this place satisfied that I have laid truth before you.

The CHAIRMAN: Before Dr. Croft goes away, we return our thanks to him for his valuable communication.

Dr. CROFT: I beg to thank you. My profession is that of medicine. It is supposed we should keep to the orthodox; but I do not see why we should not make use of our minds to promote the interests of other professions.

"MEANS OF SCREW-SHIP STEERAGE, AND A DESCRIPTION OF THE HYDROSTATIC STEERING-GEAR FITTED ON BOARD H.M. SHIP 'ACHILLES,' WITH THE RESULTS OF EXPERIMENTS AT SEA; ALSO PLAN OF APPARATUS FITTED ON BOARD THE TURKISH IRON-CLAD 'FETHI BULEND.'"

By Rear-Admiral E. A. INGLESFIELD, C.B., F.R.S.

It is notable that for several years, "offensive" as well as "defensive" preparations for maritime war have been carried on by European nations, with an energy which, as regarded the one or the other, was deserving of a more marked success; for example:—In this country the manufacturers who strove to perfect a weapon which should possess sufficient strength to burn a charge of powder capable of projecting an enormous missile with high velocity and marvellous powers of penetration, have succeeded so well, that their labours might have been described as eminently successful, had there been none to devise a more perfect protection for the sides of our war-vessels than existed in the days of wooden line-of-battle ships. But so it is, that these inventors of guns and projectiles, have been met, at every step in their advance towards an anticipated success, by naval architects and engineers, who rivalled their zeal, and who have produced with equally successful results, armour-casing and other devices in the construction of war vessels, which defy the efforts of the gunner, and make next-to-nought of the penetrating powers of the heaviest ordnance which can be carried on board our ships. Thus, in reference to our great guns for ship use, we literally find, as regards the work required from them in penetrating a ship's side, that they are somewhat inferior to those obsolete weapons which were thought so perfect, and which proved so effective in the days of Nelson.

In any future maritime war, great speed, heavy armaments, and ponderous armour will be the qualifications of the combatants on both sides,

for foreign nations have not been slow in following our example, and at times in taking the initiative.

Among naval Officers there are divided opinions; eager advocates for this as for that principle of attack and defence, can it be doubted that when the hour for actual conflict has arrived, that, with the modern appliances of steam, huge cannon, charged with heavily explosive missiles, devilish devices in the shape of torpedoes, and beyond and above all, the wholesale destruction which the ram prow will carry before it—I say, can it be doubted but that when once the belligerent squadrons are ranged in opposing lines of battle, the combat will be brief and bloody? That each, then, in his turn and place, should aid by example, precept, or device, in making our war ships as perfect as possible, is unquestionably the duty of every naval Officer.

It is not my purpose in the following pages to discuss either of those qualifications which constitute the warlike capabilities of our vessels, with reference to armaments or armour. I propose to speak of what relates to that element in the capabilities of a fighting ship, without which armaments are comparatively valueless. I allude to the locomotive properties of our vessels of war, and especially that element which gives to a ship all the value of its locomotive powers—I mean the method and self-contained ability to direct and vary the course—when proceeding at the highest rate of speed, with the greatest rapidity, certainty, safety, and precision.

A naval writer makes the following apt remarks upon this subject. He says,—

"In all fighting ships there is one especially weak point which, if successfully assailed, at once places the vessel *hors de combat*, and leaves her entirely at the mercy of the enemy. This point is the steering apparatus, the destruction of which leaves the ship a useless log upon the water, unable even to run away, unless Providence had previously placed her head in such a position as might admit of such a manœuvre being possible. No matter what may be the perfection of every other part of the ship, no matter though her battery be impregnable and armed with irresistible weapons, all can be rendered absolutely useless by one well directed blow at the steering apparatus, which in all vessels, whether old-fashioned or new, is more or less exposed. Not only is the apparatus exposed, but the men at the wheel, put them where you will, are liable to be swept away, and the ship at a critical moment left helpless, either before an evil-disposed enemy, or in the vortex of a storm."

This is the point at which I am aiming in first speaking of modern improvements. It will hardly be credited that at this moment there are only three of our powerful iron-clads which, not having been fitted with balanced rudders—a comparatively modern introduction of Mr. Reed's—possess the means of obtaining the full effect of their rudder-power according to the designs of their builders, and when I say this of our own ships, I am not far from the facts, in asserting that in this respect we are not inferior to foreign nations. I do not impugn the authorities for this apparent negligence in the equipment of our war ships; I believe the Admiralty and the Chief Constructor of the Navy,

are thoroughly alive to this great want, and it is only because the rapid strides of our shipbuilders and engine manufacturers in the production of long fast ships, have found no one to keep pace with them in the development of some plan or system, whereby may be ensured a safe, certain, and rapid control of the helm, when high velocity is the rule of action.

It is thus that in the noblest and most perfect specimens of naval architecture ever produced, and which are worthy of our importance amongst maritime nations, we find, with three exceptions, the same antiquated appliances for steering as were used on board the grandly ornamented craft in the days of good Queen Bess.

Those who take an interest in these matters must have had the facts to which I allude brought vividly before their minds, if they perused the graphic letters in the *Times* from its correspondent on board the Channel Fleet, during its recent summer cruize. It was stated by him that on one occasion the "*Minotaur*," which carried the Admiralty Flag, was for a short time quite ungovernable in a heavy seaway, through the inability of the united efforts of *fifty* men to steer the ship—so impotent was the power of her steering gear! I think under these circumstances, that any Officer who may have the opportunity and leisure, with a certain amount of experience, to collect and embody data on this important subject, will not be toiling in unprofitable ground; and thus I take upon myself, after some years' experience, and no little amount of thought and study, to improve my own observations by a careful comparison with that of other workers in the same field—men who are well qualified to speak, not only from their official positions and scientific attainments, but from the result, in some cases, of well devised experiments.

The able papers read before the Institution of Naval Architects, on the subject of "screw-ship steerage," by Vice-Admiral Halsted, Mr. Barnaby, Assistant-Constructor of the Navy, as well as Mr. Barnes, of the same department, have afforded me much valuable information, and I shall quote from them largely, as doubtless their opinions will have more weight than any words of mine, and I am desirous of establishing my case, as regards the existence of a great *want*, before offering, as the excuse for my theme, the *remedy*.

I have said that as far as my unofficial knowledge went, there were only three of our first class iron clads with any mechanical arrangement for steering, other than the old fashioned, long tiller, with its many fathoms of hide rope led along vulnerable spaces to a cumbrous wheel placed on the quarter-deck, supplemented, it is true, by what is called the fighting-wheel in some more secluded part of the ship, but still dependent for its utility on the same tiller, rope gear, and a gun's crew of men.

The three ships in favour of which I make an exception, are the "*Northumberland*," "*Monarch*," and the "*Achilles*," the two former having steam steering-gear, and the last, a particular adaptation of hydrostatic-hydraulic-apparatus, concerning which I propose to speak more fully later on.

The steam steering-gear fitted on board the "*Northumberland*" and

"Monarch" is an adaptation of steam-power to the ordinary barrel around which the tiller-ropes are coiled; this barrel is placed between decks, and has a most ingenious automatic arrangement, so as to meet the demands of ordinary steerage.

Mr. Gray, the patentee and inventor, has well illustrated the capability of steam to perform this service, and I believe that nothing can be more perfect than the action of his engine; *but*, for fighting purposes, there still exists the long tiller and tiller-ropes, and there must be steam in the boilers, *and to spare*. On board the "Northumberland," I was informed, that while the small steering-wheel on the upper deck could be worked with facility by one man, the rapidity of action as regarded the rope-barrel was such as to require the constant attendance of a seaman to keep the turns from riding. A stoker was also frequently in waiting upon the engine.

Before I go further into the general question of the "steerage of screw ships," I will for a moment draw attention to the accompanying diagram, taken from a well digested paper, written by a distinguished mechanic, Mr. Froude, on the subject of the hydrostatic steering-apparatus on

board the "Achilles." He illustrates the case of the "Cadmus," which got ashore last year at Salcombe, not far from Torquay. "She *all but* cleared the rock; a little greater speed in getting the helm over would have enabled her to clear it altogether." He says "In fact if the ship with her helm at the best angle can form a circle with radius $c a$, she will *at once* begin to move in that circle, if the rudder is *at once* brought to that angle, and she will follow the course $a b$ in the diagram, whereas if time elapses in getting the helm over, she will follow some such imperfect curve as $a a'$, till the proper angle is gained, and only then will she begin to move in the circle. A vessel going 12 knots goes 1,200 feet per minute, and if it takes 63 seconds instead of 30 seconds to get the helm over, she will have gone fully

"800 or 900 feet more towards the point which it is desired to avoid."

The foregoing pre-supposes that the power *exists* for obtaining a full rudder-angle, though *time* is required to accomplish it; what then if the greatest rudder-angle obtainable, be only 15° instead of the 35° or 40° for which the helm has been "bearded?" This I shall presently show is the normal state of our war-ships' steering abilities.

To follow up the case of the vessel *a*, exemplified by the diagram, it is clear that had she been supplied with an apparatus which could have commanded a rapid movement of her rudder to its extreme angle, and so diverted her course with greater rapidity from the impending danger, a catastrophe would have been avoided; in other words the vessel would have turned in a smaller circle, and thus covering less ground, would have avoided the dangerous locality.

It would appear, then, from the foregoing, that if it were possible to put the helm over to its extreme angle in two seconds, the risks of collision with another vessel, or stranding upon a rock or shoal, would be greatly lessened; but it must be borne in mind that the power necessary to produce such a result must be so enormous, when applied with such rapidity, that it would almost amount to a blow, and that it might, and probably would, end in wringing the rudder head, or fracturing the tiller, or some of its appurtenances.

Perhaps, in the mind of a sailor there would exist another disadvantage. If the steering-apparatus is constructed to put the helm over to a maximum angle in so short a space of time as two seconds, it would be impossible to give the oft required and most necessary quick *small* helm, which is the perfection of steerage, unless a provision were made which could throw the rapid-movement-action in and out of gear at short notice; a complication very undesirable where huge forces are concerned. To meet all the demands on the helm, I think 30 seconds a fair allowance of time to get a helm hard down.

And now to review for a moment the present position of the steering capabilities of some of our largest ships of war.

I find Mr. Barnaby stating in the paper which he read before the Institution of Naval Architects, that "the 'Warrior' and 'Black Prince,' in turning a circle, traversed a space so great, that in passing through 90° they would have to travel nearly half a mile." He adds, "that in these ships the ordinary means of steering were as perfect as they can be made." Further on he says, "that in nearly all our screw-ships the men at the wheel cannot hold the rudder at the extreme angle for which it is bearded, but have to exert all their force, when the vessel is at full speed, in order to hold the helm at 15° or 16° ." What this force is, and what the number of men required to exert it, is well illustrated by three occasions, one very recently in the case of the "Minotaur," to which I have previously alluded, another, when experiments were being made with the "Black Prince," when, to quote from Mr. Barnaby once more, "she was turned completely round in $8' 33''$, the rudder being over to 28° , but in order to hold it there it required 10 men at the wheel, and 30 at the relieving tackles, no less than 40 men being employed at this operation. This, says he, is of

"course an extreme case, but it serves to show that *an invention which promises to reduce the number of men required to one or two, has great claims to consideration.*"

Thirdly, my own experience, when in command of the "Prince Consort," an iron clad of 4,000 tons, on an occasion of experimental circle-turning, I placed eight men at the wheel and 25 men at relieving tackles in my cabin, and at full speed they were unable, with their utmost efforts, to obtain a full rudder-angle. "Rudder-surface," and "rudder-angle" are the qualifications which constitute the whole value of "rudder-action," and no one will dispute that these must form very important considerations in the ship-builder's plans.

I am not in a position to state what is the rule or standard by which the "rudder-surface" for any particular vessel is calculated, but I have little doubt that the length and draft of a ship, taken together, constituting what may be termed the longitudinal wetted or immersed area, form one of the principal guides in the determination of rudder-area; and this seems natural enough, for a vessel of great length must necessarily demand a greater leverage on one extreme to cause her to move out of the direct line of course in which she may be progressing, than a ship of half her length. Whether or not this be the rule in determining rudder-area, it affords a very fair standard of comparison, and I propose to notice the proportions of such areas in a few cases. I find that at mean load draft—

	Rudder area.	Longitudinal immersed area.
Himalaya has	1 foot	to 60 feet
Achilles	1 "	" 58 "
Warrior	1 "	" 51.5 "
Black Prince	1 "	" 51.5 "
Defence	1 "	" 48 "
Arethusa (screw)	1 "	" 47 "
Royal Oak	1 "	" 44.4 "
Arethusa (sailing)	1 "	" 41.3 "
Ariel	1 "	" 37.3 "
Hood	1 "	" 35 "
Terror	1 "	" 23.8 "

Admiral Halsted, in his elaborate paper on "screw-ship-steerage," referring to the above says, "A mean of the proportions shown by the steaming *Ariel*, with full rudder-surface and full rudder-angle, the sailing *Arethusa*, and the both sailing and steaming *Hood* has been taken as forming, on the basis of experience, a just standard of what proportions between rudder-area and immersed longitudinal-area, all naval, if not mercantile, screw ships should possess, in order to realise full 'screw-ship-steerage.' This mean gives 1 foot of rudder-area to every 38 feet of immersed longitudinal-area; and tested by this standard the 'Warrior' and 'Black Prince' show a deficiency in rudder surface of 62 square feet or 34 per cent. The 'Defence,' and vessels of her class, show a deficiency of 35 square feet or 25 per cent. The 'Royal Oak,' and her class a deficiency of 26 square feet

"or 17 per cent., and the 'Achilles' a deficiency of 86 square feet, or 53 per cent. Thus, if the standard itself, and the means of obtaining it, be judged fair and practical, and the calculations correct, then no charge for defective powers of turning in our large armour-plated ships can be substantiated, nor ought to be made, against either the ships themselves or the true application of the true screw in the only true place for it, viz., the dead wood in front of the rudder, while these grave primary defects still remain unremedied."

The foregoing will show there exists a great disproportion of surface-area in the rudder of vessels enumerated; whether other conditions have determined this disproportion I know not, but I think we shall be able to detect a reason in the paper of Mr. Barnes, from which I shall have occasion to quote in treating of rudder-angles. From my own observation I can say, that having cruised both in the Channel and Mediterranean squadrons with several of the vessels named, I have often had cause to observe how various and limited were their powers of turning at all speeds; and here I must speak of another cause which probably contributed largely to this short-coming, viz., a want of full rudder-angle, whether due to a lack of room for proper tiller-action, or equally, want of ability to obtain a full rudder-angle through the feebleness of steerage power.

Now these are qualifications which so seriously affect the steering qualities of a vessel, that they must not be lightly regarded.

In vessels (such as the "Warrior") having screw-wells, to obtain a proper sweep for her tiller, a yoke has been fitted somewhat similar to a gig's yoke in principle, though the necessary gearing was varied. In ships without screw-wells, a full length straight tiller is employed, and the ordinary threefold reeving of tiller-ropes. Under these conditions it would appear that no difficulty could exist in giving the tiller any amount of rudder-angle, *provided* power sufficient is always at command. Now what do we find stated by a high authority on this subject, after a series of experiments made in the "Terror," at Devonport.

Rear-Admiral Key says that the officer in command of the Reserve Fleet at Portsmouth, had remarked the same want of command over the rudders of our screw-ships at full speed which had been observed by himself and Admiral Halsted. The experience at both ports being that in ships of above 400 N.H.P. only one had commanded a rudder-angle of 20° from which they had sometimes fallen to 11° only.

Admiral Key says in another place: "I can distinctly state that I found a decided advantage of both time and space in every additional degree of angle up to 40°, the limit to which the 'Terror's' tiller could work. Between that and 45° I found advantage as regards space, but a very little as regards time. The old limit of 32° was made for sailing-ships, as of course it was inadvisable to stop their way, but with screw-ships the more you stop their way the better."

We now arrive at the point which I think explains the varying proportions in the rudder-areas, still, however, referring to rudder-angles, and remembering that it is admitted the power did not exist for obtaining the full rudder-angle for which it had been bearded.

Mr. Barnes in his scientific review of the "Relation between the powers applied to turn the ship," tells us, that "assuming the powers applied to the steering-wheel to be equal in both cases, a ship will turn more quickly with a small rudder than with a large one, because the angle at which the small rudder can be put over, is greater than the angle at which the rudder of greater area can be put over.

"In our large iron cased ships, also in the Mersey class, and in high powered ships of the merchant navy, the inclination of the rudder obtained with the usual power at the wheel when the ship is under full steam, is about 15°. If under these circumstances rudders had been fitted so that with the same power applied at the wheel, the inclination would have been 30° then (without going through his algebraic equations) it may be briefly put—

Small rudder. Large rudder.

$$b = B \frac{\sin. 15^\circ}{\sin. 30^\circ} \text{ (from equation (1)) } = \frac{1}{2} B \text{ very nearly.}$$

"Again the effect of the rudder to turn the ship in the two cases will be as sin. 30° to sin. 60° or as .5 to .866, or as 1 to 1½.

"It is clear then that if the breadth of the rudders of these ships be reduced one half, and an inclination of upwards of 30° be obtainable, the same power applied at the steering-wheel will produce with the narrow rudder nearly double the effect produced with the wide rudder, and consequently the ship will describe a circle of about one half the diameter of that described with the large rudder."

And here, I take it, lies the real difficulty with regard to the standard of the proportions for rudder surface, viz., that *the size of the rudder has to be kept within dimensions that can be controlled by steerage power*, but once let us acquire that necessary force, equal to any demand of rudder-area, and the rudder-surfaces of our ships may be restored to their full dimensions, and a greatly increased duty will be the result.

Mr. Barnaby asks in following up the subject of rudder-areas, and the forces we can apply—

"Is the rudder large enough to absorb, and to absorb economically all the power we can put upon it? There are in fact certain considerations which show, that as a general rule, our rudders are too large." Mr. Barnes concludes, "that rudders which cannot be worked at large angles are not economical, and should be reduced in area until they can be worked." "If," says Mr. Barnaby, "a problem of maxima and minima be constructed expressive only of the first two conditions here laid down, it appears that the rudder would be most effective in turning the ship if it were over at an angle of 54¾°, but if the fourth or economical condition be also brought in as one of the conditions of the problem, so as to discover with what angle and breadth of rudder a given power on the wheel may operate most effectively on the ship, the angle comes out 45°, and of course the breadth of rudder such that the power will just maintain that angle.

"Although this undoubtedly shows that rudders which can only be

"worked at 15° or 16° are too large, yet I am afraid that the necessities of a ship, which must be sometimes under sail and sometimes under steam, will limit improvement in the ordinary rudder in this respect, for a rudder which could be held hard over when under steam would certainly be too small when under sail."

Doubtless, with these considerations fully before his mind, and alive to the great importance of obtaining a full rudder-angle with a large rudder-area, Mr. Reed, the Chief Constructor of the Navy, not finding an available power to obtain this full rudder-angle with sufficient rudder-surface, has wisely adopted, as the only apparent alternative, the balanced-rudder in its simple form, as fitted to the "Bellerophon," "Monarch," "Inconstant," "Invincible," "Audacious," "Vanguard," "Iron Duke," and "Hotspur," in its more complex form of jointed-balanced-rudder in the "Hercules" and "Sultan." In all these vessels yet fully tried, the practical as well as mechanical effect is all that can be desired. It is, however, very necessary that the proportions before and abaft the line of axis should be nicely determined; it is also requisite that the officer commanding a ship fitted with a balanced-rudder should thoroughly understand the peculiar properties of this form of rudder, or he may be liable to pronounce a hasty judgment which at a later day he must recall.

There is no evidence, as far as I am yet informed, to prove that the balanced-rudder may not be as safely hung, and as securely placed, as the ordinary stern-post rudder.

An accident which occurred to the balanced-rudder of the "Inconstant," and of which so much has been made, in no way affected the principle. In that ship there were special reasons for making the body of the rudder for the most part of brass; this was the first time that brass had been employed for the purpose, and there was consequently a want of data to go upon in determining the sizes and proportions required for the various parts, which in this case happened to be done in a dockyard. In addition, it appeared after the accident, that the casting was somewhat defective at the part where fracture took place, although no defect could previously be discovered by the closest inspection.

These were the causes of the accident, and they were obviously independent of the form of the rudder, that is, whether balanced or simple, while the experience then gained is likely to prevent the occurrence of similar accidents in other ships with brass rudders.

It should be explained that the jointed-rudders of the "Hercules" and "Sultan" are brought into an altered condition from a balanced rudder to that of an ordinary rudder when under sail; they then lose all their mechanical advantages of easy motion by the ordinary steering wheel, and we must under such circumstances be content with a loss of rudder-angle.

It may be useful here to give some idea of the times of turning ships with ordinary and with balanced-rudders, in order fully to appreciate the mechanical advantages of the new system; this may be obtained from the following figures, shewing the results of official trials at full speeds of the iron-clads now in the Channel Squadron.

As the differences between the lengths and proportions of the ships doubtless had a considerable effect on their performances, the lengths and breadths are also given.

Ships.	Rudders.	Length.	Breadth.	Time of turning a complete circle.	Diameter of circle.
		ft. in.	ft. in.	min. sec.	Yards.
Minotaur.....	Ordinary rudders.	400 0	59 4 $\frac{1}{2}$	7 38	939
Northumberland* ..		do.	do.	7 25	812
Agincourt		do.	do.	8 20	977
Warrior	Balanced rudders.	380 0	58 4	9 10	1050
Hercules		325 0	59 0	4 0	562
Monarch		330 0	57 6	4 40	609

The foregoing table shows that the mechanical difficulty of getting the helm over for want of a sufficient power to apply to the tiller, is well met by the application of the balancing principle to the rudder, while a far larger surface is exposed to the action of the cylinder of water set in motion by the ship's engines. The nearer, therefore, we approach in our rudder-surfaces to the diameter of that cylinder of water, the nearer we undoubtedly arrive at the maximum turning power, which a given set of engines, in a given ship, at a given speed, at a maximum angle of the helm, can produce.

In estimating the value of steerage experiments, it should be borne in mind that a screw-ship will always turn quicker in one direction than in the other; this is due to the action of the column of water driven by the screw having a greater effect on one side of the rudder than it has on the other.

Practical experiments show that the ship turns quicker to the side on which the blade of the screw is revolving *descends*.

If a rudder be left free when the ship is going at speed, it will be found that the helm will incline some degrees from the line of keel. It is clear then that a screw-ship in steering a straight course, must carry a certain amount of either port or starboard helm, according as the screw is either right or left-handed, and in turning circles, this angle should be taken as though the helm were amidships.

There are those who may be content to leave matters, as they were satisfied that what has stood us in such good need for so many years, answering all the purposes of ordinary steerage under all ordinary circumstances, will suffice for the future; but to those I would say, the every-day circumstances under which our ships put to sea, and navigate in all parts of the world, are no longer *ordinary*, but *extraordinary* circumstances; and if this be true for the every-day life of a ship, how much more true will it be, when all the extraordinary self-contained

* The "Northumberland's" steam-steering-gear was used in this trial. With only ordinary steering appliances (similar to those of the "Agincourt" and "Minotaur") at work, she took 8 min. 9 sec. to go round a circle of 1,013 yards diameter.

powers of our war vessels are strained to their utmost extent in the day of battle; this seems to be the general opinion of naval Officers and naval architects generally. To quote from Admiral Halsted once more, he says,—

"Whenever a fleet of, say twenty such ships as the "Warrior," in "close order, shall be suddenly signalised to manœuvre, or change their "formations for battle in face of an enemy, and gun after gun from the "Admiral enforces rapidity of evolution, there can be no stopping of "engines to put helms over, unless with the certainty of confusion, if "not collision. But on the other hand we may rest assured that that "Fleet will be found best prepared for the emergencies of that day, "which shall be best provided with the means of using the greatest "rudder-power which the highest engine-work in each ship can give; "and such a provision when realised for the Navy, may be equally as "valuable to the commercial screw-ship also, in the dark nights or "foggy day, as means of increased safety from collision, with ship or "shore, iceberg or reef, or water-logged derelict."

Mr. Scott Russell, in discussing the paper on "Screw-Ship-Steering," says,—

"So long as any ship in the Navy does not possess the power "of immediately—on the order being given—putting the rudder, which "shall be of an adequate size, hard over to 45° , and keeping it there "so long as the Officer in command of the ship desires it shall be kept "—I say as long as every ship in the Navy does not possess that "power—somehow or other, those who put these ships into the hands "of commanders are answerable. I am perfectly satisfied that, in "iron steam-ships at least, we can so construct the sterns of the ships "in regard to strength, we can so construct the tiller of the ship, and "we can so put convenient mechanism on the end of those tillers, as to "accomplish the end in view."

On another occasion the same gentleman, speaking on the same subject, says,—

"It is perfectly manifest, I am sure, to every practical man, that if "it be necessary for manœuvring to keep yourself out of danger, or to "run into mischief when you want to do so, if it be necessary to have "good steering power at a low velocity, it is infinitely more necessary "that with a ship that runs into mischief very fast, you should have "infinitely more control, and as more control can only be got by a "large rudder, controlled by large power, we are shut up very much "into the position of taking hydraulic power, or something else, and "compelling the big rudders of the big ship to go round."

Mr. Reed winds up his remarks on the paper from which I have so largely quoted by saying:—"I think the whole object of Admiral "Halsted's paper was to show, that you must have more steering- "power, and then you can do everything. That is what we all pretty "well agree with."

Having now established my case on the highest authorities, viz., that a great demand exists in the present day for a mechanical steering-power equal to the task of putting over to an angle of 45° the largest rudder that may be deemed proportionate, according to the immersed

longitudinal section of a given vessel, without any reference to the power employed, I come to the question of "means" to that "end;" and in justice to the subject and the labours of others working in the same field, I must first allude to the form of steam steering apparatus which exists on board two of the three ships I have previously named.

The steam-engine of this machine is in gearing with a barrel, round which the tiller ropes are coiled, the barrel is made to revolve rapidly at pleasure in one direction or another, and thus the helm is put over either way in a very short space of time; but as a long tiller and tiller ropes are employed, there still exists the danger of the tiller or tiller ropes being shot away in action, or the accidental carrying away of either, besides the continual drawback of stretching in the rope-gear. As I before remarked, in the "Northumberland," though one man can manage the small steering-wheel, it requires a seaman and a stoker to be more or less in attendance on the engine.

In the form of steering apparatus which I have fitted to the "Achilles"—the other of the three ships named,—I have endeavoured to overcome the objections to a long tiller and tiller ropes; to the necessity for more than one man to steer the ship; and, above all, to the dependence on steam to be able to use the apparatus at all.

My engine I have called an "hydrostatic-hydraulic-steering apparatus," and I use the word "hydrostatic" because I employ as a motor power the pressure which exists at the bottom of every floating body, more or less, according to the depth of water at which that body floats.

To utilize this power (which roughly is half a pound per square inch for every foot of draught), I admit through a Kingston-valve in the bottom of the ship, the external water, and convey it to an ordinary horizontal or upright cylinder, in the most convenient lowest space available in the bottom of the ship.

The water so admitted, is made to work a piston in the cylinder by an ordinary tappet-motion; the piston has a rod moving with every stroke of the piston in a double-action force-pump. Now the power obtained by this form of apparatus is as the number of square inches contained in the area of the piston multiplied by the number of pounds due to the height of the column of the external fluid, and thus increased, concentrates its maximum force at the delivery of the water from the force-pump. The machine fitted for the first experiment on board the "Achilles" was much too large for the work required, and gave an ultimate pressure (as shewn in the gauge) equal to 600 lbs. on the square inch. The application of this extraordinary power to the purposes of steering the ship is simple enough, the water from the force-pump is conveyed through a directing-slide, which is the governor and directing power of the engine, to two hydraulic-cylinders placed on either side of a 4 feet tiller.

The rams working in these cylinders are connected with each other, and have a stout steel pin at their junction. It is by this steel pin that the tiller is connected with the rams; a moveable fork working in a clutch made to slide on the tiller, forming the method of connection, and

also giving the necessary freedom requisite for adapting the extreme positions of the tiller to suit the direct thwartship-movement of the rams.

The directing-slide is so arranged that the movement of a properly adapted piston working in a cylindrical chamber, through a space of five inches, will turn the high pressure water of the force-pump to either tiller-cylinder, or at its middle point place the two tiller-cylinders in free communication with each other, while at a point midway between the central positions and the extremes of the up or down strokes of the directing-slide, all the apertures are closed, and the water in the two cylinders locked in their chambers. The movement to the directing-slide is given by a miniature wheel placed in the pilot-house on the bridge, with a duplicate on the lower deck placed under armour plate protection.

I have only given a general outline of the form of "steering apparatus" fitted on board the "Achilles," as I read in this theatre last year a paper describing it fully, with explanatory drawings, and I shall presently describe the form of improved apparatus being now fitted to the Turkish iron-clad corvette "Fethi Bulend," by Messrs. Kittoe and Brotherhood.

I must not, however, omit to give the results of the experiments made with the apparatus on board "Achilles."

Captain Luard in his official report of a full speed trial outside the breakwater at Plymouth says:—"The ship was steered with this apparatus on various courses without any difficulty, and with considerable accuracy, the lower wheel was also used in the same way, communication being kept up from the bridge by voice pipes.

"The chief points of advantage shown by this apparatus were these:—

"1st. Sufficient motive power always available.

"2nd. The steadiness with which the power applied overcomes the resistance of the rudder at the highest rate of speed, especially when the helm is nearly hard over.

"3rd. The security with which the rudder is held at any desired point.

"4th. The readiness with which the rudder is freed after being hard over, and thereby allowed to right itself rapidly when going at speed.

"5th. The ease with which the power is applied, one man being able to use it under any circumstances.

"6th. The facility with which the tiller is connected with, or disconnected from, the hydraulic rams."

At the time these experiments (which lasted four hours) were made, it had not occurred to me to test what effect upon the ordinary steering-wheel of the ship, would result from keeping the hydrostatic apparatus connected, but on a future occasion it was proved not to make any appreciable difference in the facility of action, whilst it demonstrated the unquestionable advantage of being able, when steering the ship in the ordinary way, to put the ordinary hydrostatic apparatus in action at an instant's notice.

Fig. 1.

M A I N D E C K

The first trial of the apparatus showed that the power exerted was enormously in excess of the demand on the tiller, for, as I stated before, the gauge showed a pressure sometimes amounting to nearly 600 lbs. on the square inch, while the actual force necessary to put the helm hard down either way when the ship was going at full speed, did not exceed 150 lbs. on the square inch. There was a slowness of action in the movement of the water-engine reported by Captain Luard, but to remedy this was not a difficult task, as it required only to convert the large surplus *power* into *speed*. The slowness of the engine was due to two causes; the main from the Kingston valve had been made to perform such a tortuous route to avoid the magazine floor, that before the external column of water could reach the water-engine, it had to pass six quick bends, thus greatly reducing its force; the passages also into the water-engine had been made too small by some mistake in the working drawings.

At the final trial, after making some alterations to remedy these defects, a result was obtained which quite equalled my most sanguine expectations. A quotation from the reports, and a private letter from Captain Nolloth, will form the best conclusion to this description.

Officially, it was reported by the Captain "that in all cases the helm went over to about 25° in 10 secs.; the maximum angle obtained by the ordinary wheel being $24\frac{1}{2}^{\circ}$ in 1 min. 17 secs.

"When the apparatus is connected, the ship can be steered by it, or by the ordinary wheel, without any considerable extra strain being thrown by one on the other. The chief engineer of the 'Achilles' (Mr. Lewis) informs me that the working of the machinery of the apparatus was quite satisfactory."

Privately, Captain Nolloth writes to Admiral Halsted, in answer to his queries about the trial:—"I am sure you will be glad to learn that on Saturday we returned to Portland after a *most satisfactory* trial of Inglesfield's apparatus. With it we can put the helm over to about $33\frac{1}{2}^{\circ}$." He adds:—"It is beautiful to think of one man—a boy even—being able, with a little unpretentious wheel on the bridge, by a turn of the wrist, to direct with ease the course of this huge mass, and moreover to hold the rudder in a heavy sea-way under a control unattainable by means of the ordinary tiller-ropes. Inglesfield may well feel proud of his success."

From the Admiralty I have received an official letter, in which the Secretary states that:—"My Lords have great satisfaction in informing you that the reports of the trial of your hydrostatic steering apparatus, since the alterations, are satisfactory, and show that it will be a valuable instrument in the 'Achilles.'"

Since the successful results of the experiments on board the "Achilles," Mr. Reed has directed the application of my hydrostatic-steering-gear to a Turkish iron-clad corvette building under his superintendence.

A description of this apparatus will be brief; it is smaller and simpler than that fitted to "Achilles."

In the plan (see Plate iv) which accompanies this paper is shown a section of the after part of the "Fethi Bulend," now fitting with my

steering apparatus. On the keel of the ship, under the engine-room floor, is placed the water engine, E, and which consists of a cylinder 24 inches in diameter, with a piston having a 1 foot stroke. The piston-rod is arranged as the plunger of a double action pump, P, and the movement of the piston and power is obtained by the pressure of the external column of water (equal to $\frac{1}{2}$ lb. per square inch for every foot of draft) being admitted through the bottom of the ship by a Kingston valve, K, shown in Fig. 2, a sluice valve, I, and main, II, communicating with the slide-box, L, fitted at the side of the power-cylinder water-engine.

By a simple arrangement, the movement of the power-cylinder is automatic, and continues to work so long as the directing-slide is open to either side of the tiller-cylinder. At each stroke, up or down, of the piston in the power-cylinder, water is forced into the pump, P, at a pressure multiplied by the difference between the areas of the bucket and piston. The surplus water from each stroke falls into the bilge, and is taken off by the bilge pumps. The forced water thus raised to a mean pressure of about 300 lbs. on the square inch, is conveyed by the pipe F to a directing-slide, D, Fig. 1, and from thence by two pipes, F', to either side of the after part of the ship, and there connected with two rams, R R, Fig. 4, working in a cylinder, C, which moves with the tiller, T, and adjusting itself to the angle by means of a sliding clutch, U, on the tiller.

The directing-slide D (Fig. 1) is the governing power of the engine, and to move this up and down through a distance of about 5 inches, or in a cock, through half a revolution, is all that is necessary to steer the ship.

The small steering-wheels W and W', one placed in the chart house on deck, and the other on the lower deck under armour-plate protection, are the appliances by which the directing-slide is moved, and it is only necessary to turn either wheel through three-fourths of its diameter to cause the helm to go from hard-a-starboard to hard-a-port. Placing the midship-spoke at either extreme marked port and starboard (see Fig. 5); the helm will go over without any further action of the helmsman. When the midship-spoke is placed within the arcs marked black on the dial-plate, the helm will become locked, whatever its position, and when the midship-spoke is placed in the centre, the helm will right itself, without any movement of the water-engine, for the action of the water passing the rudder, rights it by its own force. Moreover, if the tiller-ropes are rove, when the hydrostatic-steering-wheel is in this position, the ordinary steering-wheel may be used, and no appreciable difference (as regards friction) can be discerned.

In conclusion, I may say that I believe all the conditions necessary to ensure a powerful, ever ready, rapid, economical, and easily managed steering apparatus are to be found in the form of engine I have proposed. Moreover, there can be little doubt that some such apparatus is much required; and that the demand is an urgent one, may be gathered from the expressions of an official authority, who has thought and written much on this subject, ending his remarks upon one occasion by saying,—“In whatever manner future naval engage-

“ments may be conducted, the result of those engagements must largely depend upon the course which is now taken in providing machinery for steering; but in view of contests between ships cased with armour and equipped as rams, this question takes the very first place.”*

The CHAIRMAN: I am sure you will all join me in returning our sincere thanks to Admiral Ingfield for his very valuable paper. As an old sailor, I must say that I quite rejoice to think that this invention has been brought forward by one of my brother officers. I wish him every success, and I am sure you all do. It is not only we, but the whole country must be indebted to him for his very valuable invention. I am delighted to think that the Admiralty should have taken up the invention warmly, and that the results should have been so satisfactory.

Vice-Admiral HALSTED: Admiral Ingfield has been kind enough to mention my name in connection with this subject, to which I have devoted many years of effort in trying to bring it about. I most sincerely and warmly congratulate Admiral Ingfield, and I most sincerely and warmly congratulate ourselves upon the success of his invention. I would simply repeat that last sentence which he has read; the whole question is contained in it. I have paid great attention to his application of the apparatus in the “Achilles,” not during its progress, but after its completion. I have been down to Portland twice for the express purpose of making myself master of it, so far as my ability would enable me to do so. Nothing could exceed the completeness, as far as I could apprehend it, of the whole application. But there is a point beyond that, and I think it is a very large point. I will not take long to express it, because of the shortness of the time at our disposal. I do believe that what Admiral Ingfield has done for us is really and truly the commencement of a very great and generally applicable discovery to many purposes, far beyond those to which he has now applied it. It is the more remarkable,—it makes one almost smile to think about it,—that every ship we have, each and all, has been carrying about with her this self-contained or self-accompanying hydrostatic power, and we have never been aware that it could be adapted for our benefit in so many ways as I believe it is almost inevitable that it will be. I no more believe that that little, I was going to say, “contemptible thing,” that is able to exercise that power of 300 lbs. per square inch for moving a mere tiller from starboard to port, will be limited to such work only, than I believe that the power of the ordinary steam-engine has yet found its limit of application. There is not a foot of that ship’s bottom that will not give you, if tapped, the means of working an apparatus for doing something of the same sort as working the tiller. The power is always there; it is constant, it is costless; it is instantly applied. You have only to turn a cock, and there it is; you do not want to light a fire. I am perfectly convinced in my own mind, though I may be speaking hazardingly, but it is my impression, so far as my examination of the “Achilles” goes, that this discovery of Admiral Ingfield’s is capable of performing for us all sorts of valuable services. I have laid upon him this bond already, that he makes it turn our turrets, that he makes it work the guns in the turrets, makes it get up our anchors, and moor our ships. I do not see why it should not also pump ships. In coming to that point, there is a grave question with regard to it on which I venture to think more highly of his discovery than he does himself. He thinks that the apparatus cannot be made to pump out its own water. I think not only that it can, but I say again that the multiplicity of purposes to which he can apply those little apparatuses, will depend very largely on their being enabled to pump out their own water. Now, I will merely mention one idea which has crossed my own mind before coming here, and the minds of others also, with regard to the means which it possesses of doing this work for itself, and getting rid of its own waste water. He spoke of an

* P.S.—Since this paper was written, I have submitted plans to the Admiralty, showing that the same apparatus employed for steering can be readily adapted for turning the heaviest turrets.—E. A. I.

excess of power for the tiller work as having been produced in his first engine, in which he got 600 lbs. per square inch, and he says he now finds that 300 lbs. per square inch is ample power by which to work the tiller. Very good. I merely throw it out as a possible suggestion; why could not the other extra 300 lbs. per square inch be made, as it were, to protrude through the end of the piston, not the rod, but the case also, which he makes the means of getting up his hydraulic pressure, why should not such waste power be made to act externally through that or some yet more suitable means, and then you have got 300 lbs. per square inch available to set any other apparatus in motion, perhaps even in the same line. Admiral Inglefield has mentioned the able assistance he has procured from the engineers whom he has employed, the Messrs. Kittoc and Brotherhood. I perfectly agree with him in his commendation. After examining both the original engine in "Achilles," and knowing pretty well what improvements and simplifications the present engine is capable of, I am sure he could not express himself otherwise than highly grateful towards them. But I do think this—if I am right in my estimation—that what has already been done is a mere indication of what we may yet derive from that apparatus, and that the ablest and most experienced of our mechanical engineers are not a bit too good to be put into possession of the principles of this apparatus, and to be appealed to, so far as it is competent to do so, to aid us in developing what further services can be procured out of this practical discovery, as I regard it, which Admiral Inglefield has brought before us.

Captain JASPER SELWYN, R.N.: I am going to ask your permission to raise a point which I am afraid Admiral Halsted has forgotten. There is a certain process which goes on after you have let water into a ship, which requires power to get rid of it. He will kindly remember, that if he multiplies his engines, he must multiply the amount of water let into the ship, and that it is perfectly vain to attempt to get perpetual motion in any way. I am sure when he thinks of it twice, he will see that it cannot be done. I should be sorry that engineers should go away with the idea that naval men think that they can lift themselves in a basket. As regards the invention of Admiral Inglefield, I join most heartily in the congratulations which come to him from all sides, on the extreme ingenuity of his adaptation of the broad principle of hydrostatics which he has developed. I do so the more warmly because I had the pleasure many years ago of being his messmate; and we all know how warmly messmates always feel towards each other. With regard to the power as applied to the rudder, it is a beautiful expression of force applied to that particular purpose. But I submit that that force ought not to be required to be so applied, that it is an error to require it, and that it is as unnecessary to develop that force, which Admiral Inglefield now does, in the rudder in opposition to the water, as it is to the fish, who never does any such thing. When the fish, as Dr. Croft has shown us, wishes to turn himself, he does so by a very slight curve introduced into a flat surface. I must say that my views are entirely opposed both to the ordinary flat rudder and to the balanced rudder: more to the balanced rudder even than to the flat rudder, because as I see in the table before me, showing different lengths of ship and different rates of turning, the increased time which must be given to the increased length of the ship in the different ships themselves. I see the balanced rudder is doing much better, but we have not quite brought out how much is due to the changed shape of the ship, and what is due to the changed shape of the rudder. Until we do that, we cannot be able to define exactly what is the value of the balanced rudder. Next, I say the balanced rudder becomes a mistake the instant you put it over, not 32° but even 30° ; the instant you do so, you introduce a force which tends to break the rudder in half in the centre. The quicker the ship is going, the more the water thrown off by the screw, the more you are trying to break your rudder in two. It is held at both ends, and you are applying the force in the centre which tends to break it. I dislike the balanced rudder, if we can do without it; and I think people will join me in saying, generally, that of all the disgraceful, ugly objects that were ever stuck on to the stern of a ship, and on an ugly stern, too, there never was a more disgraceful exhibition than that balanced rudder. It certainly does not follow nature in any sort of way; I do not think there is a fish in existence that would not be ashamed of it. Still, taking the machinery of the hy-

draulic press or pump, such as Admiral Inglefield has developed there with the assistance of Messrs. Kitto and Brotherhood, I think he has done the most we could possibly expect in so short a time to develop the utmost simplicity and the best results. I have no more to say than to congratulate him most warmly upon that development, and to hope that he may go forward; and not only give us a better application of power to the rudder, but a better rudder to apply the power to.

Captain J. O. ROSEASON, R.N.: I wish to make one or two observations on Admiral Inglefield's paper. It must be evident to all present that he has clearly demonstrated that if the long, fast, ships are so slow in turning, it is simply due to a deficiency of rudder-area, together with a lack of mechanical power sufficient to force the helm over to the required angle. Therefore, all that we have been doomed to read in the public journals, with respect to the economy and efficiency of short-ships, has been, as I always contemplated it would be, proved to be erroneous. In truth the marked gain in time whilst performing the complete circle, as shown by the "Bellerophon" over the "Warrior" and "Achilles," is mainly traceable to the increased size of the rudder-area of the former ship, combined with the facility of rapidly putting the helm down to a far greater angle.

This is what might have been safely predicted, from a careful comparison of the times taken in making the complete circle, by the "Warrior," "Achilles," "Pallas," and "Bellerophon." The "Warrior" and "Achilles" are both 380 feet long, or 80 feet longer than the "Bellerophon"; but the difference between the draught of water, aft and the draught of water forward, is no less than five feet in the case of the "Pallas" and "Bellerophon," whilst the two former long ships draw only one foot more water aft than forward—in plain truth, the little "Bellerophon," of 4,246 tons burthen, draws exactly the same water aft, viz., 26 feet 5 inches, as the "Warrior," of 6,039 tons; consequently, the "Bellerophon" has not only a far greater area of rudder in proportion to her size, but having also a balanced rudder, the helm can be moved over to a far greater angle and also with much greater rapidity—points of infinite value where the ship is moving at a very high velocity.

The official returns of the performances of the "Pallas" and "Bellerophon," in my possession, will still further serve to illustrate this point, and tends clearly to uphold the correctness of Admiral Inglefield's reasoning, and forcibly demonstrate the value of his invention. The "Pallas" is only 225 feet long; "Bellerophon" 300 feet. The "Bellerophon," consequently, is 75 feet longer than the "Pallas," or nearly as much longer than the "Pallas" as the "Warrior" is longer than the "Bellerophon," yet we find that the short "Pallas," that has not a balanced rudder, takes 4 minutes 12 seconds to make the complete circle, whilst the long "Bellerophon" performs the same in 3 minutes 59 seconds. This simple statement of facts makes powerfully in favour of Admiral Inglefield's exposition of the case.

Nobody will deny that, *ceteris paribus*, the shorter ship will turn in less time and space than the longer vessel; but the marked difference in the time required by the "Warrior" to complete the circle, viz., 9 minutes 8 seconds, and the "Achilles," 7 minutes 17 seconds, must be traceable to other causes than to their greater length. This also is conclusively demonstrated by comparing the times occupied by the "Warrior" and "Achilles," two vessels of equal length, in making the complete circle, for we perceive that the "Achilles" takes nearly two minutes less time than the "Warrior," a marked difference when the size and immersion of the ships, both forward and aft, are nearly identical.

Many have lately listened to a very interesting paper, read at the Institution of Civil Engineers by Mr. Grantham, who has satisfactorily demonstrated the advantages to be derived from increasing the length of all ocean steamers in proportion to their beam, and we cannot fail to congratulate Admiral Inglefield in having so ingeniously and scientifically invented the means of effectually steering these long vessels, without having occasion to resort to the cumbersome machinery as at present employed in combination with the balanced rudder.

Admiral INGLEFIELD: I think there is hardly anything for me to reply to, in the shape of a question. I can only say, in reference to Admiral Halsted's suggestions, as to other work that may be done by my apparatus, that I have sent in plans to the Admiralty, and they are before the Controller at this moment; a process by

which (exactly the same sized engine as that shown in the plan) we shall be able to steer the ship and turn both turrets, merely adding to it an accumulator which will be placed beside it; this will turn a turret of 300 tons weight round its own circumference in three-quarters of a minute. These plans are already before the Admiralty, and I hope they will be tried as Admiral Halsted has suggested. Seeing Mr. Brotherhood before me, I think the meeting ought to recognize his aid, and that of his partner, in carrying out my plans, and putting them into ship-shape form. One word with regard to what Captain Selwyn has said.—I must borrow for a moment Doctor Croft's fish.—The question of merely shifting the helm is one thing; but I think it must be borne in mind that a fish has got a jointed backbone, which a ship has not. Therefore, we must be content, not having that jointed backbone, to move the rudder in the only convenient way. I hope this remark will suffice for his question. I have nothing further to say than to thank you for the kind attention you have paid to my address, and for the flattering terms in which it has been received.

LUMLEY'S PATENT RUDDER.

By HENRY LUMLEY, Esq., Assoc. I.N.A.

THE Lumley-Rudder differs from the ordinary rudder in having a recessed instead of a flat surface; and the recessing of the Lumley-rudder is consequent upon its being made in two pieces, the outer portion making a greater angle than the inner.

The advantage of this over the common rudder has been fully demonstrated in practice under every conceivable circumstance and in every class of vessel, and it has been constantly shown that a rudder, with a recessing surface, is eminently adapted to produce quick responsive action in any vessel to which it is applied.

The sensitiveness of a ship to the movement of her rudder depends on the nature of the resistance of the rudder to the currents of water flowing past the ship as she proceeds onward; also to her form, trim, and rate of speed.

Taking the first feature, the resistance of the rudder, or in other words, the force exerted at a point furthest from the ship's centre of motion, it is apparent, as in the example of the lever, where the more the force applied at the longer end the greater will be the result at the shorter, that the more pounds-weight of pressure of water that is exerted against the rudder, a greater corresponding effect will be produced on the vessel's direction, and as the recessing rudder collects, retains, and locks up the water which also strikes the best part of the rudder at a more acute angle than it would otherwise do, the force exerted and the result produced are both greater than they would be with a flat surface rudder.

There is also the double percussion of the lines of water forming the current, for they first meet the inner part of the recessing rudder, and